A Visualization Based Analysis on Dynamic Bandwidth Allocation Algorithms for Optical Networks

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Abstract
Dynamic Bandwidth Allocation (DBA) methods in telecommunication network & systems have emerged with mechanisms for sharing limited resources in a rapidly growing number of users in today's access networks. Since the DBA research trends are incredibly fast-changing literature where almost every day new areas and terms continue to emerge. Co - citation analysis offers a significant support to researcher s to distinguish intellectual bases and potentially leading edges of a specific field. We present the visualization based analysis for DBA algorithms in telecommunication field using mainstream co-citation analysis tool—CiteSpace and web of science (WoS) analysis. Research records for the period of decade (2009-2018) for this analysis are sought from WoS. The visualization results identify the most influential DBA alg orithms research studies, journals, major countries, institutions , and researchers, and indicate the intellectual bases and focus entirely on DBA algorithms in the literature, offering guidance to interested researchers on more study of DBA algorithms.

Keywords:
component; Dynamic bandwidth allocation, Citespace, Document co-citation analysis, Citation burst, emerging trends

1. Introduction

Dynamic bandwidth allocation (DBA) is a method, which allows traffic bandwidth capacity to be distributed on demand as well as reasonably among multiple users of that bandwidth in a common shared communications medium. This is one of the technique used in bandwidth management and is quite similar as statistical multiplexing in concept. In which the sharing of a link adjusts to the instantaneous traffic requirements of the linked access points in a certain way [1], [2].

DBA algorithm uses many shared network characteristics: (1) Usually all users do not really remain connected to the network at one time (2) And even if connected, users do not send data (or voice or video) at all times (3) Most of the traffic volume is bursty in nature i.e. gaps exist between information packets which can be packed with many other data traffic. Different network protocols have completely different methods of implementing bandwidth allocation efficiently. These techniques are indeed typically generally defined in standards that are developed by regulatory bodies such as the ITU, IEEE, FSAN, or IETF. One excellent example is defined in the ITU G.983 specification for the passive optical network (PON)[3].

DBA methods have emerged with mechanisms for sharing limited resources in a rapidly growing number of users in such access networks. These networks have also improved considerably over the years by increasing their bandwidth. Furthermore, QoS parameters are included in the bandwidth sharing procedure. These networks have however improved substantially over the decades by continuing to increase their bandwidth. Furthermore, QoS specifications are included in the bandwidth sharing operation [4].

Since telecommunication, network & systems are one of the major research fields with incredibly fast-changing literature where almost every day new areas and terms continue to emerge. Keeping track of each gradual improvement in one's particular research subdomain can be very difficult. Keeping in mind, this research contributes by presenting the bibliometric analysis of DBA algorithms in the telecommunication field. Research

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records for the period of decade (2009-2018) for this analysis are sought from Web of science. In the rest of the paper, Section II presents the data, methodology, Section III presents result findings in details, and Section IV contains conclusions.

1. data and methodology

The research data for this paper are retrieved from the Clarivate analytics - Web of Science (WoS) database 8 Jan 2019 for the period from 2009 to 2019-A decade. The bibliographic data contains the complete record, cited references of articles, conference proceedings, review papers in English-language, summarized in figure 01, and table no 01. The search was carried out on all four WoS indices, including SCI-EXPANDED, SSCI, A&HCI, ESCI and is fine-tuned which exclude data from completely irrelevant disciplines like Biology, Psychology etc. We obtained a record of total 2421 research publications on topic selection “Dynamic bandwidth allocation OR DBA” was downloaded from 2009 to 2018. The records contain information related to authors, title, years, and research institutions.

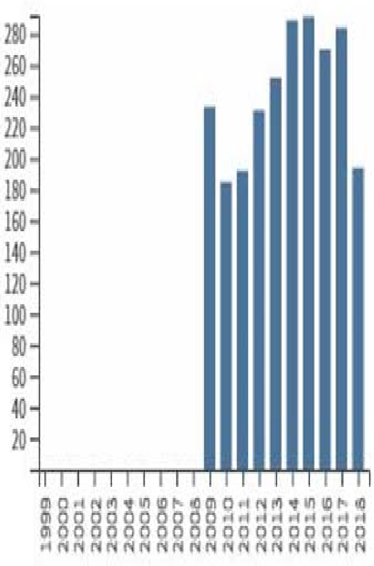

Figure 1-a. Total Publications by Year

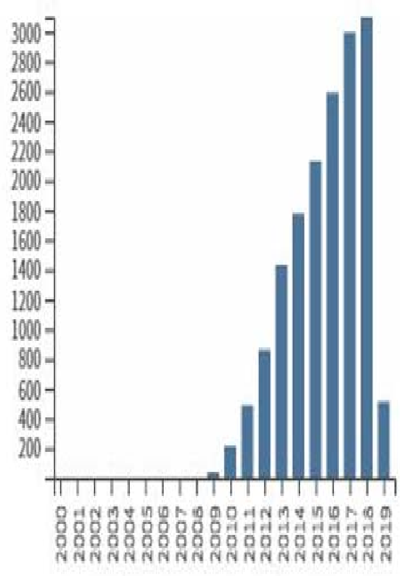

Figure 1-b. Sum of Times Cited by Year

TABLE I. Citation summary of the WoS record

Duration	2009-2018
Total No of records	2421
Sum of the Times Cited	16128
Without self-citation	14041
Citing Articles	12837
Without self-citation	12133
Average Citations per Item	6.66
h-index	52

The record analysis per year confirms that there is growing research studies being done on the efficient distribution and utilization of bandwidth allocations. With the rapid development of information technology over the past several decades, the scientific visualization of bibliometric analysis has been achieved. Many tools are used to investigate the evolution of scientific issues, including CiteSpace [5], VoSviewer [6], Pajek [7], and CitNetExplorer [8].[9], [10] identified CiteSpace as a bibliometric software that facilitates the visualization of knowledge domains and enriched with clarity and interpretability of visualizations with diverse visual analytic functions. Compared to the other existing visualization tools, CiteSpace is more balanced and powerful[11]. We use CiteSpace and WoS analysis in this research, focusing on detailed co-citation analysis, Author, Institution, Country, University and source category.

3. Result Findings

A. Results Generated from Author Co-Citation Analysis

The concept of CiteSpace is primarily based on general theory of co - citation analysis and pathfinder network scaling algorithms, which allow CiteSpace to pinpoint the major development pathways, and trends of a particular subject. Intellectual turning points actually play major roles in development and formulation of scientific domain. By recognizing such turning points, CiteSpace can find one subject's development path, which is useful for researchers to comprehend the topic and catch trending research issues or topics. Cited reference is a major aspect of co-citation visualization, which can properly categorize the most influential studies in a particular research domain. The time frame is set at 1 per slice from 2009 to 2018 for all the results findings of this paper and relative node type is changed in each analysis. Here we select node type as cited reference, and the strength among links measured by the Cosine metric:

$$Cosine\ (x, y) = \frac{CxCy}{||Cx||||Cy||}$$

Where Cx Cy show the co-citation number between two papers x & y and denominator shows the times cited of the two papers respectively. The top 50 citations within each time slice were used for the analysis. Figure 1 shows the detailed outcome of ACA, i.e. co-citation network including 405 nodes and 1294 links. Modularity Q value (quality of cluster network formed) of the findings is equal to 0.726, which denotes that the network is reasonably divided into tightly coupled clusters. The mean silhouette value (indicates the similarity in the clusters) of 0.4108 indicates that the homogeneity of the clusters is fair.

Links in document co-citation networks convey the frequency of citing two articles together in another article in a data set[12]. Each dot in the visualization symbolizes a node in the network that is a cited reference. The merged network with nodes and links shows the development of a knowledge domain over a specific time by highlighting significant publications with labels. These significant publications, given table no 02, are the highly cited references that can be considered as landmark papers in the knowledge domain.

In Figure 2, citations with large nodes represent the frequently cited publications and suggest that these papers contribute substantially to the DBA research. Therefore, Assi [13] is one of the frequently cited publications important for constructing the DBA research base. This article is published in IEEE journal on selected areas in communications and present differentiated services supported DBA algorithm that distributes bandwidths effectively and reasonably among end users. This DBA proved to exceptional research contribution with acceptable local queue management to mitigate inappropriate behavior for certain traffic classes. Table. II mentions the titles, citation count (CC) and reference of the landmark papers in the field of DBA for the aspirant researchers.

B. Identification and Interpretation of Clusters

CiteSpace analysis facilitates more precise ways to identify some prominent groups in a data set, known as clusters. Each cluster distinguishes a different domain [12]. Modularity and the mean silhouette scores indicate the properties of each cluster. If the modularity is relatively high, the network is divided into loosely coupled clusters. Further, a higher silhouette score suggests that the homogeneity of the cluster is high [23]. Cluster labels are assigned from each cluster's noun, and the noun phrases are retrieved mostly from the publications ' titles, keywords, and abstracts. Top-ranked noun phrases were chosen as the labels for the cluster. Specialized metric, namely, Log Likelihood Ratio (LLR) is used to identify the most significant clusters of DBA mechanisms and their most significant terms. LLR test identifies the uniqueness of a term to a specific cluster [5]. Cluster identification is shown in figure 03 and Analysis of cluster information, given in Table III in details guides that the largest cluster (#0) has 45 members and a silhouette value of 0.835. It is labeled as passive optical network by LLR. The most active citer to the cluster is 0.1801BUTT, RA (2018) with title "Sleep assistive dynamic bandwidth assignment scheme for passive optical network (PON)". The second largest cluster (#1) has 45 members and a silhouette value of 0.985. It is labeled as elastic optical network by LLR. The most active citer to the cluster is 0.1351BA, S (2017) with title "Defragmentation scheme based on exchanging primary and backup paths in 1+1 path protected elastic optical networks". The third largest cluster (#2) has 40 members and a silhouette value of 0.782. It is labeled as online multi-thread polling by LLR. The most active citer to the cluster is 0.28351MERCIAN, A (2013) with title "Offline and

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online multi-thread polling in long-reach pons: a critical evaluation”

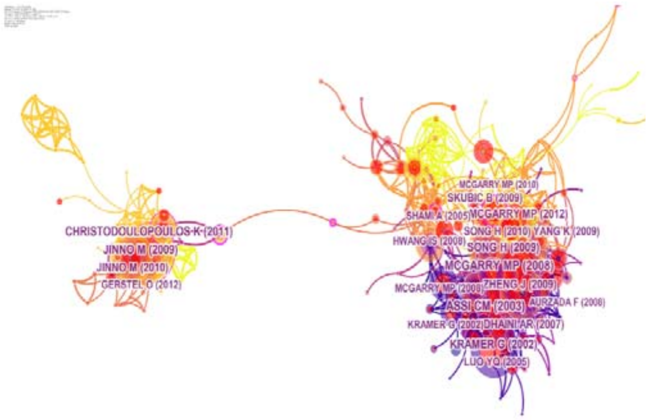

Figure 2. Document Co-Citation Analysis Results

TABLE II. Publications with Top Citation Counts (CC)

CC	Publication Title
68	**“Dynamic bandwidth allocation for quality-of-service over Ethernet PONs”** [13]
65	**“Ethernet passive optical network architectures and dynamic bandwidth allocation algorithms”** [14]
58	“Spectrum-Efficient and Scalable Elastic Optical Path Network: Architecture, Benefits, and Enabling Technologies” [15]
54	“Multi-thread polling: a dynamic bandwidth distribution scheme in long-reach PON” [16]
51	**“IPACT a dynamic protocol for an Ethernet PON (EPON)” [17]**
51	“Elastic Bandwidth Allocation in Flexible OFDM-Based Optical Networks” [18]
48	“A survey of dynamic bandwidth allocation algorithms for Ethernet Passive Optical Networks” [19]
47	“Dynamic Wavelength and Bandwidth Allocation in Hybrid TDM/WDM EPON Networks” [20]
45	“Investigation of the DBA Algorithm Design Space for EPONs” [21]
45	“Distance-adaptive spectrum resource allocation in spectrum-sliced elastic optical path network” [22]

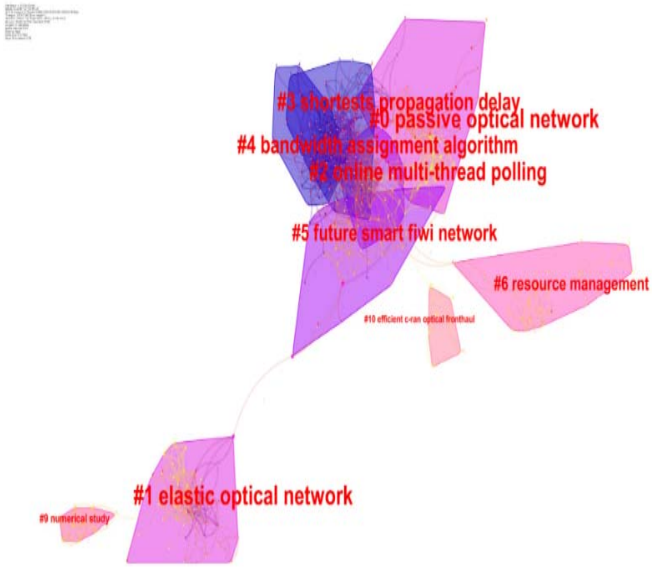

Figure 3. Cluster identification

TABLE III. Analysis of Cluster Information

Cluster #	Size	Silhouette	Year	Label (LLR)
0	45	0.835	2012	Passive optical network; assistive dynamic bandwidth assignment scheme; ITU PON; efficient cyclic sleep control framework, shortest propagation delay; DWBA algorithm
1	45	0.985	2012	Elastic optical network Advance reservation; backup path; defragmentation scheme; spectrum assignment bandwidth defragmentation, future flex grid optical network; online multi-thread polling; long-reach passive optical network scalable interleaved dba mechanism
2	40	0.782	2011	online multi-thread polling; long-reach PON; mean packet delay; low-latency polling scheme, priority-based processor sharing model; splitting-aware cloud-ready multicast, bitrate flexible optical network; hybrid dynamic bandwidth
3	39	0.759	2005	shortest propagation delay; spectrum assignment; efficient cyclic sleep control framework; resource management; intelligent dynamic bandwidth allocation algorithm, hybrid optical wireless network; energy conservation scheme, guaranteed bandwidth level

4	39	0.698	2006	offline WDM EPON; first scheduling; long-reach PON; defragmentation scheme; long-range FIWI network, cycle length, TRX energy-efficiency mechanism, adaptive polling algorithm; computational resource management, low-latency polling scheme

a. Citation Bursts

Citation bursts indicate a specific duration in which an abrupt change of the frequency takes place in the research area [24]. The results are extracted from above ACA technique where the red circle around the node represents the significant citation burst, indicating that citations of this node have emerged rapidly in a particular time period. Results in TABLE IV reveal that The top ranked item by bursts is Assi CM (2003) in Cluster #3, with bursts of **27.33**. The second one is Kramer G (2002) in Cluster #3, with bursts of **23.95**. The third is Kramer G (2002) in Cluster #3, with bursts of **13.96**. The 4th is Gerstel O (2012) in Cluster #1, with bursts of **9.07**. The 5th is Kramer G (2002) in Cluster #3, with bursts of **8.80**.

TABLE IV. Citation Bursts Results

Bursts	References	Begin	End	2009- 2018
27.33	Assi CM, 2003 [13]	2009	2011	
23.95	Kramer G, 2002 [17]	2009	2010	
13.96	Kramer G, 2002 [25]	2009	2011	
9.07	Gerstel O, 2012 [26]	2009	2010	
8.08	Luo YQ, 2005	2009	2011	

b. Journal and Conferences Co-Citation Analysis

Here, we present journal and conferences co-citation analysis for the identification of interrelated core journals and conferences in the literature of “Dynamic bandwidth allocation OR DBA”. Based on record of 2421 research publications retrieved from WOS for the period of a decade (2009-2018), we retrieve a list of top ten journals and conferences in the literature, given in TABLE V and have out them percentage wise in table so as researchers can easily recognize the top journals and conferences in this research domain.

TABLE V. Top Journals and Conferences

S.no	Top Journals and Conferences	Count and %
1	PLOS ONE	148, 6.113 %
2	Journal Of Optical Communications & Networking	100, 4.131 %
3	Journal of Lightwave Technology	61, 2.520 %
4	IEEE International Conference on Communications	50, 2.065 %
5	IEEE International Conference on Communications	44, 1.817%
6	Photonic Network Communications	41, 1.694 %
7	Optical Switching and Networking	38, 1.570 %
8	Proceedings of SPIE	36, 1.487 %
9	Computer Networks	32, 1.322 %
10	International Conference on Transparent Optical Networks	31, 1.280%

c. Country wise Research Contribution

We used here WoS analysis to find out the leading countries as per their research contribution on this selected literature topic of DBA. From TABLE VI of top five countries, we come to know that China tops with research contributions and whereas South Korea is the top fifth country.

TABLE VI. Country-wise Research Contributions

S.no	Top Countries Research Contribution	Count and %
1	China	601, 24.824 %
2	USA	521, 21.520 %
3	Canada	159, 6.568 %
4	Japan	150, 6.196 %
5	South Korea	145, 5.989 %

d. Top Universities and Research Institutes

For this last result finding, WoS analysis presents rankings of the top universities and research Institutes, where from, researchers mainly contribute for research on DBA algorithms, are put in TABLE VII. With two state key laboratories of Networking and Switching Technology and Information Photonics and Optical Communications along with six Provincial Key Laboratories, Beijing university of posts and telecommunications leads the all other ten universities and research Institutes in the list with 89 research contributions

TABLE VII. Top Universities and Research Institutes

S.no	Top Universities and Research Institutes	Count and %
1	Beijing University of Posts & Telecommunications	89, 3.676 %
2	Shanghai Jiao Tong University	45, 1.859 %
3	NTT Corporation	40, 1.652 %
4	Tsinghua University	34, 1.404 %
5	Yuan Ze University	32, 1.322 %
6	Chinese Academy of Sciences	28, 1.157 %
7	Natl Cheng Kung University	26, 1.074 %
8	Arizona State University	24, 0.991 %
9	Nanyang Technol University	24, 0.991 %
10	Natl Chiao Tung University	24, 0.991 %
11	Shanghai University	24, 0.991 %

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4. CONCLUSION

In this work, we collected 2421 records on "Dynamic bandwidth allocation OR DBA" algorithms from WoS, and conducted a visualization analysis on these studies using one mainstream co-citation analysis tool—CiteSpace and WoS. CiteSpace is especially useful in identifying an intellectual base, emerging trends of topics, hotspots, and landmarks allied with various publications in a group of publications, and subsequently generating different visualization graphs or illustrations to represent the patterns of scientific literature in a specific domain. From the visualization results, we got some enlightening observations for supporting interested researchers to make further studies on DBA algorithms:

1. The most influential studies and overview papers found, have a profound influence on the motivation and significance of the studies related to DBA algorithms.
2. Author visualization finds the most influential authors on DBA algorithms, include Assi CM, Kramer G and Gerstel O.
3. The top-ten journals and conferences in terms of the contribution to DBA algorithms are presented which prove that the key studies with high citations take an important role in improving the position of academic journals and conferences.
4. China, USA, Canada, Japan, South Korea make increasing contributions to the intellectual bases of DBA algorithms.
5. In top universities and research institutes, Beijing university of Posts and telecommunication leads the rest.

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